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PESTS NOT KNOWN TO OCCUR IN THE UNITED STATES OR OF LIMITED
DISTRIBUTION NO. 79: CORN CYST NEMATODE

APHIS-PPQ

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Pest Heterodera zeae Koshy, Swarup, and Sethi

Order: Family Tylenchida: Heteroderidae

Economic
Importance

In Egypt, infected corn is significantly stunted. Fresh and dry weights of roots and shoots are decreased almost proportionally to the nematode inoculum level (Aboul-Eid and Ghorab 1981). In India, increases in inoculum level resulted in corresponding decreases in corn root and shoot length and weight. Significant reductions in these characters could be observed at an initial inoculum level of 100 juveniles per kg of soil for one nematode population and at 1,000 juveniles for another nematode population (Srivastava and Sethi 1984b). Heterodera zeae is considered of economic importance to corn in India by Koshy and Swarup (1971), Mahajan and Chhabra (1979), and Oteifa (1978).



Heterodera zeae distribution map (Prepared by Non-Regional Administrative Operations Office and Biological Assessment Support Staff, PPQ, APHIS, USDA).

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General Distribution Heterodera zeae is known to occur in India, Egypt, and Pakistan. In 1981, it was detected for the first time in the United States in Maryland. Since then, it has been confirmed in four Maryland counties: Cecil, Harford, Kent, and Queen Annes.

Hosts Corn cyst nematode has infested a variety of hosts, although it is best known from Zea mays (corn). Other hosts include Avena sativa (oats), Digitaria longiflora (India crabgrass), Echinochloa colonum (junglerice), Hordeum vulgare (barley), Panicum sp. (panicgrass), Setaria italica (foxtail millet), Sorghum bicolor (milo), Sorghum sudanense (Sudan grass), Triticum aestivum (wheat), Urochloa panicoides (liverseed grass), and Vetiveria zizanioides (vetiver). Host susceptibility may vary due to cultivar differences in some hosts and differences in geographic populations of the nematode (Bhargava and Yadav 1978, Koshy et al. 1971, Lal and Mathur 1982, Oteifa 1978, Sardanelli et al. 1981, Srivastava and Swarup 1975, Verma and Yadav 1978).

Gram, citrus, pear, and garlic were reported as new hosts in Pakistan (Maqbool 1981). These hosts have not been confirmed.

Table 1. Measurements (μ m) of two populations of Heterodera zeae females from corn (range, mean, and standard deviation).

Character	Maryland, USA (N = 40)	India (N = 26)*
Body length (including neck)	459-796(617 \pm 77)	427-716(592 \pm 15)
Body width	275-515(366 \pm 69)	325-684(491 \pm 18)
Length/width ratio	1.3-2.3(1.7 \pm 0.2)	1.0-1.5(1.2 \pm 0.02)
Stylet length	22.4-25.8(24.7 \pm 1.0)	24-25
Stylet base to dorsal esophageal gland duct opening	3.4-6.2(4.8 \pm 0.7)	--
Head tip to median bulb valve	53.8-92.4(73.2 \pm 10.1)	--
Head tip to excretory pore	110-199(159 \pm 18)	Usually 90
Median bulb diameter	31.7-35.6(33.6 \pm 1.6)	--
Vulva slit length	31.8-34.3(32.9 \pm 0.8)	--
Anus to vulva slit distance	54.6-61.0(59.5 \pm 2.9)	--
Cuticle width at midbody	6.4-8.9(8.0 \pm 0.9)	7-9

* After Koshy et al. 1971

Characters

FEMALES (From Golden and Mulvey 1983) - Measurements (Table 1). Body pearly white, basically lemon-shaped, cuticle thin, external wall pattern zig-zag, without subcrystalline layer. Head with two annules, second larger than first. Stylet slender, anteriorly flattened knobs fairly wide (4 μ m), dorsal esophageal gland duct opening about 6 μ m from stylet base. Neck long; median bulb large, rounded valve plates well developed. Esophageal gland lobe single, size and shape variable. Excretory pore well posterior to head tip, generally at level of base of esophageal gland lobe. Two ovaries, mature female filled with eggs in various developmental stages. Vulva cone well developed, vulva slit fairly long. Egg sac generally present, small to large. Anus very small, difficult to detect, fairly close to vulva slit.

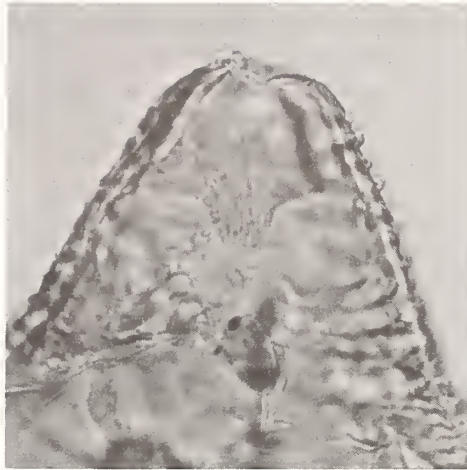
CYSTS (From Golden and Mulvey 1983) - Measurements (Table 2). Cyst light brown, basically lemon-shaped, cuticle thin walled, without subcrystalline layer. Cuticular midbody pattern zig-zag. Vulva cone prominent (Fig. 1), end-on view shows concentric lines of cuticular ridges around vulva slit and fenestra. Fenestra ambifenestrate (Fig. 2), semifenestra separated by fairly wide vulva bridge, fenestral length and width variable, basin wide but generally poorly defined. Bullae prominent, characteristic arrangement for this species: immediately below (anteriorly) underbridge are four fingerlike bullae in distinct

Table 2. Measurements (μ m) of three populations of Heterodera zeae cysts from corn (range, mean, and standard deviation).

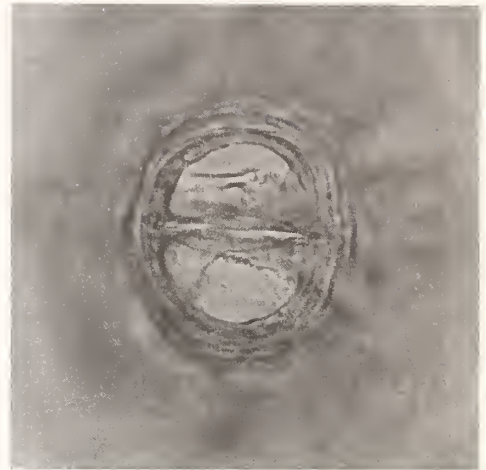
Character	Maryland, USA (N = 40)	India (N = 38)	India (N = 80)*
Body length (including neck)	454-785(588 \pm 88)	428-785(565 \pm 92)	342-684(501 \pm 10)
Body width	255-551(347 \pm 63)	245-525(280 \pm 74)	260-537(396 \pm 9)
Length/width ratio	1.4-2.2(1.7 \pm 0.2)	1.2-1.8(1.4 \pm 0.3)	1.0-1.5(1.3 \pm 0.01)
Fenestral length	35-45(40.4 \pm 3.3)	39-57(46.0 \pm 4.5)	37-53(44.0 \pm 0.8)
Fenestral width	16-34(26.3 \pm 3.9)	19-38(27.4 \pm 5.3)	20-32(27.8 \pm 0.8)
Vulva slit length	29-42(36.5 \pm 3.7)	38-45(40.4 \pm 3.5)	36-58(44.4 \pm 1.0)
Underbridge length	30-41(36.8 \pm 3.0)	34-51(38.7 \pm 3.5)	--
Underbridge width	7.6-12.0(10.3 \pm 1.4)	7.5-10.2(9.1 \pm 1.9)	--
Underbridge depth	29-38(34.6 \pm 4.7)	--	--

* After Koshy et al. 1971

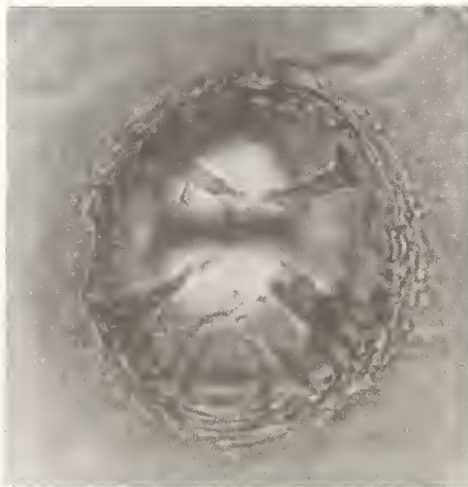
(Figs. 1-4)



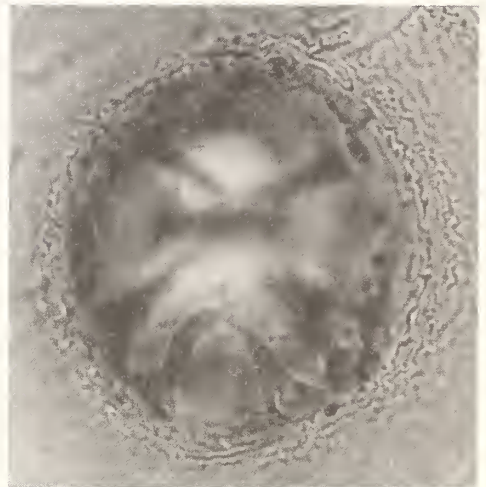
1



2



3



4

Heterodera zeae vulva cone of cysts. 1. Dorsoventral view. 2. Fenestra. 3. Four fingerlike bullae. 4. Bullae.

formation (Fig. 3). Immediately below fingerlike bullae are number of randomized bullae (Fig. 4). Underbridge simple, short, thin. Bullae formation and underbridge in nearly all cysts examined. Vulva slit fairly long, anus indistinct.

EGGS (From Golden and Mulvey 1983) - Length = $97-105 \mu\text{m}$ (102.6 ± 2.1); width = $37.8-47.2 \mu\text{m}$ (43.3 ± 2.6); length/width ratio = $2.1-2.4$ (2.3 ± 0.1). Shell hyaline, without visible markings.

MALES (From Hutzell 1984) - Measurements (range and mean in micrometers, standard deviation, N = 40): length 640.8-993.6 (806.9 ± 77.6); a = 18.9-39.9 (32.1 ± 4.3); b = 3.6-6.6 (5.1 ± 0.7); c = 105-207 (132.8 ± 27.5); stylet 24.0-24.8 (24.2 ± 0.32); dorsal gland opening 3.2-4.8 (4.0 ± 0.35) from base of stylet; center of median bulb 71.2-93.6 (82.7 ± 5.0) from anterior end; stylet knobs width 4.0-5.6 (4.7 ± 0.31); head width (hw) 8.8-9.6 (9.0 ± 0.36); head height (hh) 4.8-5.7 (5.0 ± 0.35); hw/hh ratio 1.6-2.0 (1.8 ± 0.13); spicules 24.8-32.0 (27.8 ± 1.6); gubernaculum 8-11.2 (9.4 ± 1.3); tail 4-7.2 (5.8 ± 0.7).

Male usually slender, vermiform, tapering slightly at both extremities. Head rounded, offset, with four annules and large oral disc. Cephalic framework heavily sclerotized. Midbody width 23.2-43.2 μm ($27.8 \mu\text{m} \pm 6.5$). Cuticle distinct, regularly annulate. Lateral field with four lines, center annule often narrower than outer two. Lateral field slightly more than one-fourth midbody width. Stylet well developed, knobs prominently rounded. Anterior cephalids 2-3 body annules behind head, posterior cephalids 8-9 annules behind head. Excretory pore averages 15 percent of body length from anterior end. Hemizonid 2-6 annules anterior to excretory pore. Hemizonion visible in few specimens, 2-6 annules behind excretory pore. One testis, spermatozoa apparent. Spicules slightly arcuate, tips pointed, nondentate. Phasmid small, indistinct, slightly anterior to cloacal opening, observed in few specimens. Tail short, terminus bluntly rounded.

SECOND-STAGE JUVENILES (From Golden and Mulvey 1983) - Measurements (Table 3). Body typically vermiform, tapering at both ends. Head slightly set off, rounded, with low profile, lip pattern type "4" of Stone's designation, 4-5 head annules, cephalic framework moderately developed. Stylet slender, knobs shallowly concave anteriorly. Dorsal esophageal gland duct opening close to base of stylet. Anterior cephalids 1-2 annules behind base of cephalic framework, posterior cephalids 7-8 annules behind base of framework. Excretory pore distinct, hemizonid immediately anterior to level of excretory pore. Median bulb nearly twice as long as wide, valve plates well developed. Basal part of glandular lobe generally distinct, with three large nuclei, and overlapping anterior part of intestine. Esophagus about one-third total body length. Lateral field with four distinct lines generally visible in most specimens. Phasmids very small but conspicuous, about midway between anus and anterior end of hyaline tail terminal. Tail short, conically tapering, terminus acutely rounded, hyaline terminal about one-half tail length.

Table 3. Measurements (μm) of three populations of Heterodera zeae second-stage juveniles from corn (range, mean, and standard deviation).

Character	Maryland, USA (N = 50)	India (N = 30)	India (N = 25)*
Body length	399-460(431 \pm 14)	392-451(423 \pm 15)	360-440(410 \pm 40)
Midbody width	18.5-20.7(19.6 \pm 0.7)	19.6-20.2(19.7 \pm 0.1)	--
Head height	3.4-4.5(3.9 \pm 0.1)	3.9-4.5(4.3 \pm 0.3)	--
Head width	8.4-9.5(9.1 \pm 0.2)	9.0-9.5(9.1 \pm 0.2)	--
Width/height ratio	2.3-2.7(2.3 \pm 0.1)	2.0-2.4(2.1 \pm 0.1)	--
a	20.4-23.4(22.1 \pm 0.9)	20.0-23.3(21.6 \pm 1.2)	19.0-25.4(22.3 \pm 0.3)
b	2.5-3.0(2.8 \pm 0.9)	2.4-3.0(2.7 \pm 0.2)	2.9-4.2(3.4 \pm 0.1)
c	9.3-10.5(9.9 \pm 0.3)	8.8-9.8(9.2 \pm 0.3)	8.0-13.0(8.8 \pm 0.3)
Stylet length	19.0-20.7(19.9 \pm 0.4)	19.6-20.2(19.9 \pm 0.3)	20-25(23.3 \pm 0.3)
Stylet base to dorsal esophageal gland duct opening	3.4-5.0(4.3 \pm 0.4)	3.9-5.6(4.3 \pm 0.4)	4-5
Head tip to median bulb valve	61-67(65.3 \pm 2.7)	63-77(69.5 \pm 3.1)	--
Head tip to esophageal gland lobe base	137-168(154 \pm 8)	143-182(159 \pm 20)	--
Tail length	40-49(44.2 \pm 2.4)	40-51(45.9 \pm 2.2)	52-50(41.0 \pm 1.1)
Hyaline tail terminal	16.8-25.2(21.9 \pm 1.7)	17.9-26.3(22.7 \pm 2.3)	16-30(24.0 \pm 0.7)
Caudal ratio A	2.1-3.7(3.0 \pm 0.3)	2.5-3.8(3.1 \pm 0.3)	--
Caudal ratio B	9.2-20.9(12.9 \pm 2.9)	8.0-20.0(12.5 \pm 2.7)	--
Lateral lines	4	4	4

* After Koshy et al. 1971

Characteristic
Damage

Corn cyst nematode attacks host plant root systems resulting in poor root development, areas of uneven or patchy growth, retardation of leaf emergence, stunting, and pale narrow leaves (Aboul-Eid and Ghorab 1981, Koshy and Swarup 1971, Oteifa 1978, Srivastava and Sethi 1984b). Like other cyst-forming nematodes, H. zeae has the potential for greatly reducing yields in its primary host. Its degree of pathogenicity has not been defined in Maryland yet. Distribution of the corn cyst nematode is not confined to a certain soil texture (Oteifa 1978).

Detection
Notes

H. zeae, like other species of cyst nematodes, can enter the United States in soil (even small amounts) associated with nursery stock, root crops, bags used for root crops, seeds, used farm machinery, automobiles, trucks, and other soil contaminated articles.

H. zeae has been intercepted only once at a port of entry. Fifteen cysts were found in soil around a potted succulent plant arriving from Karachi, Pakistan, on May 9, 1965. This interception was made before the species was described from India.

Soil sampling similar to that employed for the golden nematode, Globodera rostochiensis (Wollenweber), has been used to survey for Heterodera zeae in Maryland. Methods employed were designed to achieve a detection sensitivity of 500,000 cysts per 0.4 ha. At cyst densities encountered thus far, selective sampling (around gateways, low areas in fields, etc.) has proven no more effective than whole field sampling methods. Populations may be found in clumped distributions. Due to the practical necessity of cutting the corn stalks down before surveying, there is often only a short time period in which to accomplish sampling before onset of ground freeze.

Corn cyst nematode may be transported from infested fields on agricultural machinery, construction equipment, or even military ordinance. Articles which have been regulated due to the high risk they present in spread of corn cyst nematode from infested areas include soil, plants with soil, root crops with soil, mechanized farm equipment, mechanized soil-moving equipment, and any other product, article, or conveyance determined by an inspector to present a risk of spread. Most of the Maryland infestations have been associated with fields in continuous corn production for at least 10 years; the two heaviest infestations have been in continuous corn for more than 30 years for one, and more than 100 years for the other. The

infestations are all within 16 km of the Chesapeake Bay, and many are clustered around a military base that has a long-standing mission of evaluating foreign military equipment. Considering all of the environmental, cultural, and ecological factors, the history of the area, and the uncertainties about the population dynamics of H. zeae, the circumstances surrounding the nematode's introduction into Maryland are likely to remain mere speculation.

Identification of H. zeae is made from cysts and juveniles. These are submitted in a formalin-containing fixative formulated for nematodes.

Biology

H. zeae follows the same developmental stages as other cyst-forming nematodes. Males are rare. Reproduction is assumed to be by parthenogenesis (Lauritis et al. 1983). The life cycle at 24-30° C during August and September in India took 20 days from juvenile entry into corn roots to adult female full of eggs (Verma and Yadav 1975). In corn root explants at 29.5° C, white females with eggs were observed 13 days after inoculation, second-stage juveniles on the 19th day, and initial hatching was observed on the 22d day (Lauritis et al. 1983). Second-stage juveniles start emerging in water from white cysts immediately (Verma and Yadav 1978). The average number of eggs in the cyst body was found to be 237 and an average of 229 eggs in the gelatinous egg sac (Lauritis et al. 1983). Reproduction is greatest in moderately light soils (Srivastava and Sethi 1984a). No hatching occurs at or below 10° C and at or above 40° C; the optimum hatching temperature is 30° C (Verma and Yadav 1981). About 7 to 8 generations of H. zeae can be completed in a cropping season in India, which lasts from 115 to 125 days (Srivastava and Sethi 1985).

H. zeae can be found in different types of soil (Oteifa 1978). It also occurs under varied climatic conditions. In India, summer rainfall varies from 203 to 305 mm per month while in Maryland summer rainfall averages 102-127 mm per month. Winter rainfall in India is less than 25.4 mm per month; in Maryland, about 76 mm per month. Summer air temperatures in India are about 29.5° C; in Maryland, 24.5° C. Winter temperatures in India are 12.5-17° C and the soil where H. zeae occurs seldom, if ever, freezes. Winter temperatures in Maryland are about 0° C, and the soil freezes with H. zeae surviving. Cysts in frozen soil are known to survive up to 4 months.

- Control Crop rotation appears to be an effective control method against H. zeae. Hosts are confined to graminaceous plants although not all such plants are hosts (Lal and Mathur 1982, Oteifa 1978). Some are poor hosts (Srivastava and Swarup 1975). Cultivar resistance in some hosts may be exploited.
- Natural Enemies H. zeae obtained from uncultivated soil near New Delhi, India, had fungal mycelium emerging from the natural openings of about 40 percent of the cysts. The fungus was identified as Fusarium solani (Mart.) Sacc. Tests showed that F. solani reduced the number of cysts and their contents. In hatching tests, cysts containing infected eggs showed 42 percent reduction in hatch compared to cysts with healthy eggs. White females and juveniles were free from fungal infection, suggesting that F. solani parasitizes only eggs (Lal et al. 1982).
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